

Temperature Capability for In-Situ TEM Nanostage

Nanomaterials are roughly defined as solids with characteristic dimensions that are 200 nm or less. The engineering properties of nanomaterials are frequently different from typical engineering properties. For example, some newly invented composite materials that incorporate nanomaterials in their structure have very high yield strength and excellent fracture toughness. In essence, it is the very small dimensions and concurrent surface-area-to-volume ratio of the nanomaterials that give rise to these properties and make them inherently different from traditional engineering materials. In addition, it is important to be able to characterize the mechanical behavior of these materials under different temperature regimes, especially as nanomaterials and structures become used in sensors and other programmatic applications.

Project Goals

The goal of this project is to establish a new capability to experimentally measure the mechanical response of nanomaterials and structures in the Transmission Electron Microscope (TEM), over a range of temperature from 100 to 500 K. To accomplish this goal, a loading stage must be built that is compatible with the TEM, and a loading cartridge, which holds the nano-sized sample, must be fabricated to fit on the end of the stage and transfer the load onto the sample, while measuring the strain. The scope of the project is to establish and test the new capability, and provide documentation on the utility for future studies.

Relevance to LLNL Mission

This project will add to the ever-increasing capabilities LLNL engineering will need to characterize and use nanomaterials and structures. Because of their small size and unique engineering properties, nanomaterials have the potential to play a key role in the production of sensors for programmatic applications.

The first use of this capability will be to quantify the dislocation velocity as a function of applied stress in single

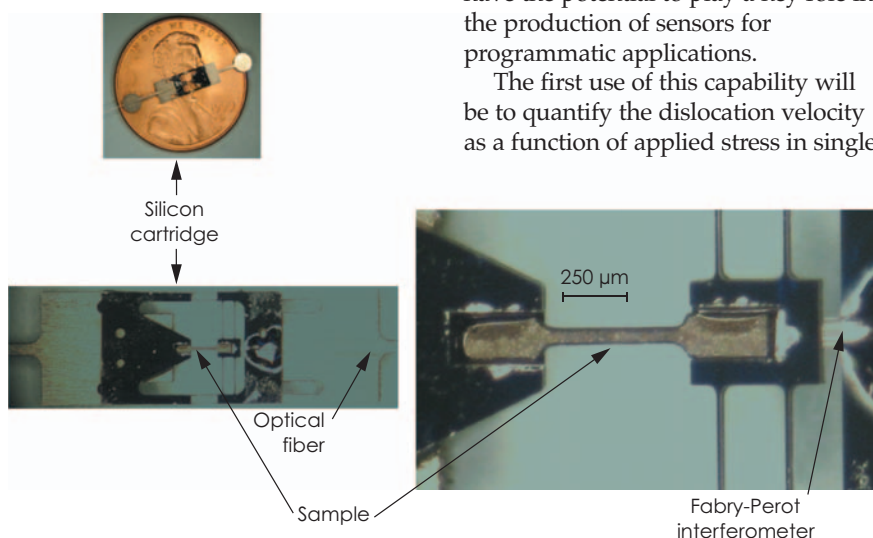


Figure 1. Photographs of the loading cartridge. Counterclockwise: the cartridge in relation to a penny; the complete cartridge; and a blow-up near the sample region.



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crystals. These dislocation mobility values have never been accurately measured, and are essential input for LLNL's multiscale modeling program.

FY2005 Accomplishments and Results

Loading cartridge. The room-temperature loading cartridge is shown in Fig. 1. A method has been devised to calibrate the cartridge. The results of the calibration (Fig. 2) show that this technique has a displacement resolution on the order of a few nanometers, and a load resolution of about 10 mN. Extending this technique to a range of temperatures requires a modification to the loading cartridge, and that modification has been completed.

Loading stage. The loading stage, which applies load to the sample *in situ*, has been configured to fit inside the Philips 300 TEM. The fabrication of the stage (Fig. 3) has been completed. This stage requires only a slight modification to the tip to extend the capability to the range of temperatures of interest. A series of temperature calculations have been completed to guide the configuration of the tip. Based on those results, the tip design is in progress and the appropriate materials have been selected.

FY2006 Proposed Work

In FY2006, the temperature tip for the stage and the temperature cartridge will be fabricated. In addition, the hardware to control the temperature in the TEM, which includes a cold finger and heater, will be fabricated. Finally, the completed system will be assembled and tested.

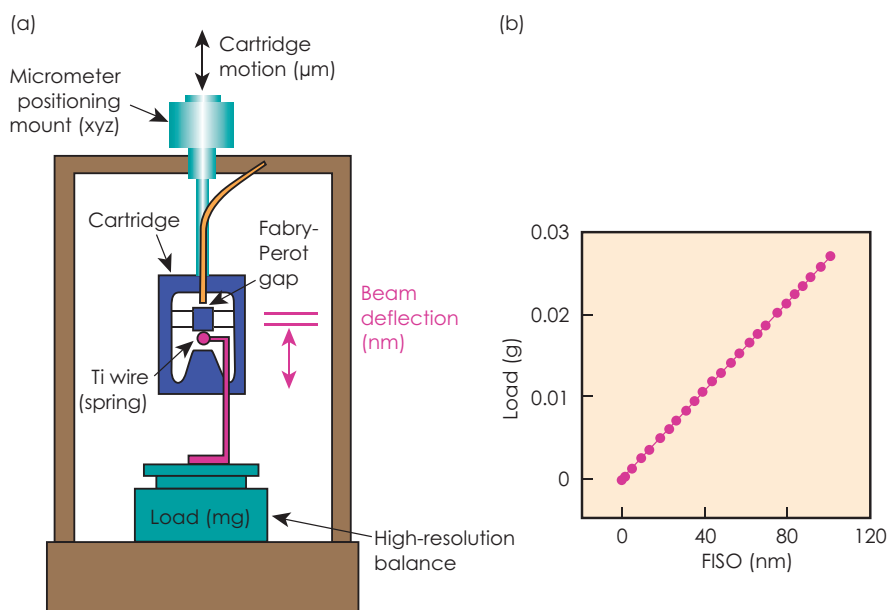


Figure 2. (a) Schematic of the calibration apparatus. The cartridge moves up and down via the micrometer, and the Ti wire applies a force to the beams in the cartridge. The load is measured with a high-resolution balance, and the displacement of the beams is measured by the Fabry-Perot interferometer. (b) The corresponding calibration curve, showing the expected linear response and verifying the high load and displacement resolution of the technique.

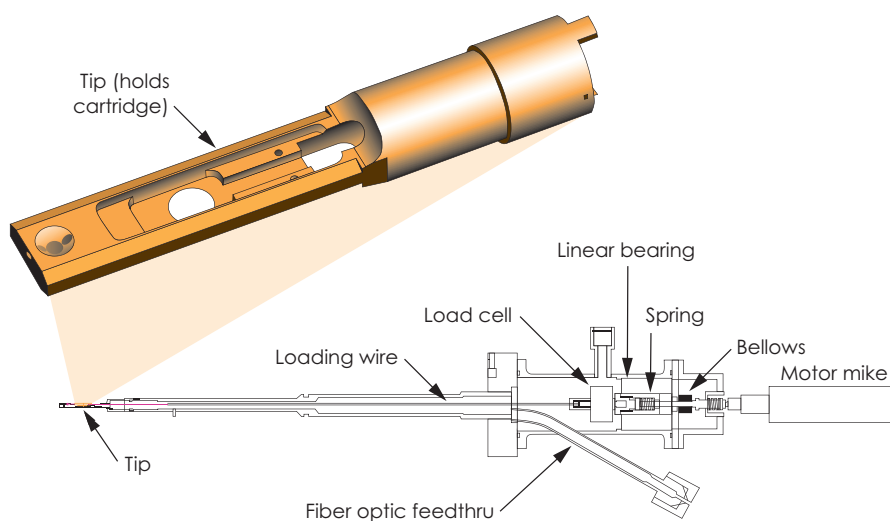


Figure 3. Schematic of the loading stage.